

atmosphere at velocities up to 22,700 feet per second. The nosetip sensor indicated that initial ablation occurred near an altitude of 191,000 feet at a velocity of 22,700 feet per second. Before and during nosetip ablation, SHARP-B01 dynamics were nominal.

These flight results validate the preflight expectations of the UHTC nosetip performance. Arc-jet tests, integrated design tools, and now flight data all

demonstrate the material's ability to operate at a temperature of 5100°F before it degrades.

The results of this flight demonstration of sharp leading edges have generated great interest in the aerospace industry.

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Arc-Jet Flow Characterization

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Arc-jet facilities have been used extensively to evaluate materials for use in the thermal protection of aerospace vehicles, from Apollo spacecraft and the shuttle to the X-33 and the X-34. Although arc-jet tests are indicative of how well a material will perform in extreme aerothermal heating environments, it has not been possible to directly relate arc-jet test results to flight applications. The main obstacle has been an inability to determine the total enthalpy of the nonequilibrium arc-jet flow, and its distribution among kinetic, thermal, and chemical modes. The objective of this work is to develop diagnostic techniques to determine these quantities, thereby improving our understanding of the relationship between arc-jet test and flight environments.

As part of this effort, a laser-spectroscopic instrument has been developed to characterize the flow environment by measuring the free-stream enthalpy in large-scale arc-jet facilities. This approach involves making flow-property measurements using two-photon laser-induced fluorescence (LIF) of atomic nitrogen; it was recently demonstrated in a series of tests conducted in the Aerodynamic Heating Facility (AHF). The flow properties, which include velocity, translational temperature, and species concentration, were measured simultaneously over a range of facility operating conditions. When combined with facility measurements of mass flux and pitot pressure, an analysis of the flow properties obtained using the two-photon LIF

technique yields the kinetic, thermal, and chemical enthalpy components of the free-stream flow directly; the total flow enthalpy is calculated from the sum.

Example two-photon LIF excitation spectra from atomic nitrogen obtained from the arc-jet flow and from a flow reactor, which is used to calibrate the arc-jet measurements, are presented in the first figure as a function of the dye fundamental wavelength.

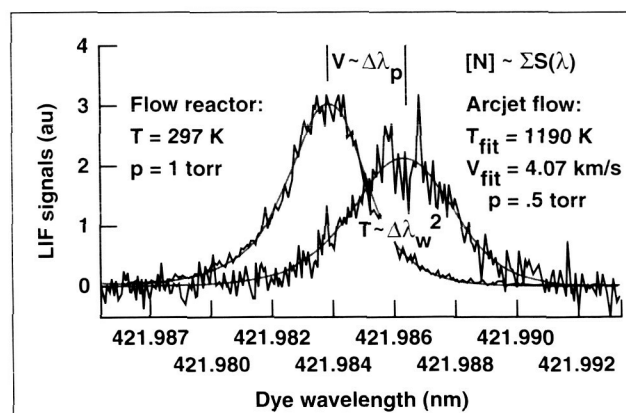


Fig. 1. Excitation spectra from two-photon LIF of atomic nitrogen from the arc-jet flow and from the flow reactor. The narrower spectrum is from the room-temperature, low-pressure flow reactor; the broader spectrum is from the higher-temperature, lower-pressure, nitrogen/argon arc-jet flow.

Nonlinear, least-squares fits to the spectra using a numerical model of the two-photon absorption line shape are also shown for both the reactor and flow data. The thermodynamic conditions of the flow reactor are given in the figure. The arc-jet flow conditions were deduced from the spectra by using the analytical methods that are summarized in the figure: velocity is determined from the Doppler shift of the absorption line center; translational temperature is derived from the absorption line width; and atomic nitrogen number density is proportional to the spectrally integrated LIF signal.

Measurements in the AHF, which was configured with a 30-centimeter-diameter nozzle, were obtained

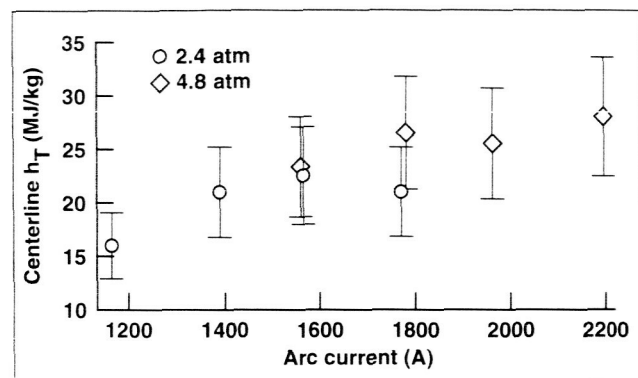


Fig. 2. Centerline enthalpy values that were measured during constant pressure, variable current nitrogen/argon flow tests conducted in the AHF. Uncertainties are indicated by the vertical bars.

during experiments in which the arc current was varied at constant pressure for two different pressures in a nitrogen/argon mixture. Experimentally determined free-stream total enthalpies for these tests are shown in the second figure; the values range from 16 megajoules per kilogram at the lowest current of the low pressure test case to 28 megajoules per kilogram at the highest current of the high-pressure test. For both chamber pressures, a trend of increasing total enthalpy with increasing arc current is indicated within the uncertainty of the measurements. Trends in enthalpy distribution among the three modes, as current and pressure vary, also provide useful insight into the kinetic processes that govern the nonequilibrium expanding nozzle flow.

Total stream enthalpy and its apportionment into kinetic, thermal, and chemical contributions in the nonequilibrium arc-jet free-stream flow have been sought for over 30 years. The two-photon LIF technique that has provided these measurements represents a unique instrumental capability, and its use in further characterization of the arc-jet facilities at Ames Research Center will establish the relationship between the arc-jet test and flight environments.

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